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Addis Ababa Science and Technology University
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School of Civil Engineering and Construction Technology

CASE STUDY: - Chancho –Derba - Becho Road Construction Project

Rigid and Flexible Pavement Cost Comparison

An Independent Project Paper in Geotechnical Engineering Stream
MSc

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September, 2016

Addis Ababa, Ethiopia

DECLARATION

The undersigned have examined the project work entitled **Rigid & Flexible Pavement Cost Comparison (Case Study:Chancho–Derba -Becho Road Construction Project)** presented by **MekonnenYilma**, a candidate for the degree of **Master of Engineering** and hereby certify that it is worthy of acceptance.

Advisor	Signature	Date
Internal Examiner	Signature	Date
Chair person	Signature	Date

UNDERTAKING

I certify this project work titled " **Rigid and Flexible Pavement Cost Comparison (Case Study :** Chancho–Derba -Becho Road Construction Project**)**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

MekonnenYilma

ACKNOWLEDGEMENT

I am deeply grateful to all who have given me assistance in the obtaining of information and data related to this project work. I am also grateful to Chancho-Derba-Betcho-Road Construction Project staff and Core consulting Engineers plc staff.

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ABSTRACT

Construction of road with cost efficiency and sustainable road pavement type is generally considered as an essential element for economic and social development our country. In the road construction industry the government of Ethiopia Ethiopian Road Authority is giving attention for the construction of rigid pavement in areas high traffic loading.
Rigid pavements have not been extensively used in most tropical countries and in Ethiopia in particular, mainly due to a lack of tradition and experience in their design and construction and due to the relatively higher initial investments. Cost of rigid pavement is more advantageous than flexible pavement for high traffic loading areas.

A total of 10km flexible pavements and rigid pavements costs are designed and their costs computed in the paper and rigid pavement cost is higher than flexible pavement cost by 41 %.

ABBREVIATION

ERA	Ethiopian Roads Authority
ERCC	Ethiopian Roads Construction Corporation
FHWA	America’s Federal high way Authority
AASHTO	American Association of Highway and Transportation Officials
ASTM	American Society for Testing and Materials
CBR	California Bearing Ratio
GM	Grading Modules
GPS	Global Position System
ESA	Equivalent standard Axle
ACI	American Concrete Institution
DS3	Design standard three
PDM	Pavement Design Manual
JUCP	Jointed Unreinforced Concrete Pavements
JRCP	Jointed Reinforced Concrete Pavements
CRCP	Continuously Reinforced Concrete Pavements
msa	Million Standard Axles
IRC	Indian Roads Congress
AC	Asphalt Concrete
DBM	Double bituminous macadam
BC	Base Course
SB	Sub base
AADT	Annual Average Daily Traffic

CHAPTER ONE

INTRODUCTION

1.1. Background to the study

Transport infrastructure is generally considered as an essential element for economic and social development as it provides the links required to make commodity or markets functions. The development of any country economically vital sectors such as industry, agriculture tourism etc. is directly dependent on the existence of a working transport system.
Due to rapid economic growth of Ethiopia, there is a high demand for cement for different infrastructural construction consumption and currently new cement factories are under construction. Debra Midroc Cement Plc is one of the recently constructed cement factories in Ethiopia, which is expected to produce 7000 tone cement per day. Apart from cement factories there are other ongoing development projects like flower farming and related development projects throughout the country. These and other socio economic developments in Ethiopia will generate high volume of traffic and the existing road will not be able to accommodate the current and future transport smoothly and satisfactorily. In order to satisfy the demand of the economy for bulk transport of cement and other production it is required to upgrade the existing roads to higher standard.

Accordingly, Ethiopian Roads Authority has entered into a contract agreement with Ethiopian Roads Construction Corporation (ERCC) for Construction of the Chancho-Derba-Becho road Construction project on June 08, 2012 with DS3 design standard and flexible pavement and 10 km road section for the implementation of Rigid pavement.

The introduction of the rigid pavement is the outcome of the rapid development of the country which has enormously increased the traffic in most of manufacturing and agricultural areas. The pavement structures of those roads which are accommodating high traffic volume and load are easily deteriorating before giving appropriate service for the intended design life and hence more durable pavement structures are required.

However, the cost implication in the change of pavement type from flexible to rigid is the demonstration of advantages of rigid pavements over a flexible pavement in heavily trafficked roads for future decision makings.

Therefore, the aim of this project paper is to evaluate and compare the cost of flexible pavement and rigid pavements in this specific.

1.2. Objectifies of the study

General Objective

- To review the general design principles of rigid pavement and flexible pavements

Specific Objectives

- To review and compare the cost of rigid pavement over flexible pavements.

1.3. Methodology

In order to fulfil the aforementioned objectivise, Firstly Detail literature review is conducted. Secondly relevant data are collected which are used during the original design period and during the execution of the works for the project selected for this case study.
Finally, analysis is made.

1.4. Limitation

The study considered only one specific project to show the comparative advantages of rigid pavement over a flexible pavement using secondary data provided by the consultant.

1.5. Organization of the thesis

This project work has been divided in to five chapters. In the first chapter introduction, background, the Objective and a brief summary of the project work is presented. The second chapter gives a brief literature review which discusses about the principle of rigid and flexible, referring to design manuals. Case of study is done within chapter three. Cost comparison and analysis results are presented in chapter four. The fifth chapter deals with the conclusions and recommendations drawn from the project.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Although rigid pavement provides a more sustainable option depending on the relative costs of materials, their whole life costs can be considerably less than flexible pavement it has not been used extensively in most tropical countries including Ethiopia. This is mainly due to a lack of tradition and experience in their design and construction. However several tropical countries have invested heavily and successfully in rigid pavements (e.g. Philippines and Chile) and their use is widespread in Europe and the USA. There appears to be no technical reason why more use should not be made of them in Ethiopia **{ERA Design manual 2002}**.

Research paper on the Comparative study of Rigid and flexible pavement is published on the Indian Journal of Roads Congress, July-September 2009{ } one of the objectives of the paper was to investigate cost implication of soil sub-grade strength and traffic loading Depending on the strength of sub-grade soil, the layer thicknesses of flexible as well as rigid pavements are affected.{ }.

2.2 Definitions

Road pavements are designed to limit the stress created at the subgrade level by the traffic travelling on the pavement surface so that the subgrade is not subject to significant deformations. The pavement spreads the concentrated loads of the vehicle wheels over a sufficiently large area at subgrade level. At the same time, the pavement materials themselves should not deteriorate to any serious extent within a specified period of time.

There are two types of pavements based on design considerations i.e. flexible pavement and rigid pavement. Difference between flexible and rigid pavements is based on the manner in which the loads are distributed to the subgrade.

Before we differentiate between flexible pavements and rigid pavements, it is better to first know about them. Details of these two are presented below:

2.3 Flexible Pavements

Flexible pavement can be defined as the one consisting of a mixture of asphaltic or bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade.

Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements. It also includes pavements that may contain layers of

aggregate that are bound together (or stabilised) with hydraulic binders such as cement and lime, but with relatively low levels of binder.
Gravel or ‘unpaved’ roads are also a form of flexible construction. Their design is similar to that of other flexible structures but the gravel itself wears away, depending on traffic, rainfall and terrain, hence additional material is required to make sure that the gravel is always thick enough.

The design of flexible pavement is based on the principle that for a load of any magnitude, the intensity of a load diminishes as the load is transmitted downwards from the surface by virtue of spreading over an increasingly larger area, by carrying it deep enough into the ground through successive layers of granular material.

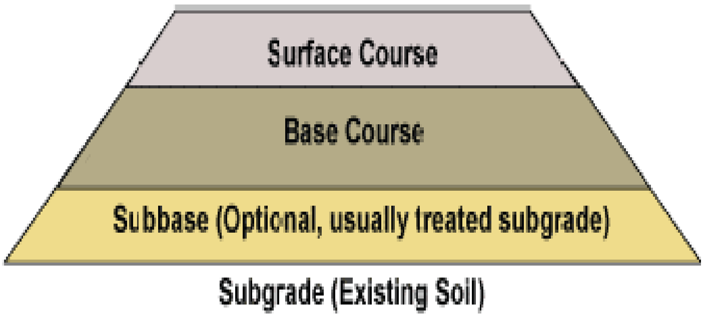


Figure 2.2.2: Flexible Pavement Cross-section

Thus for flexible pavement, there can be grading in the quality of materials used, the materials with high degree of strength is used at or near the surface. Thus the strength of subgrade primarily influences the thickness of the flexible pavement.

2.4 Rigid Pavements

A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements.

The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

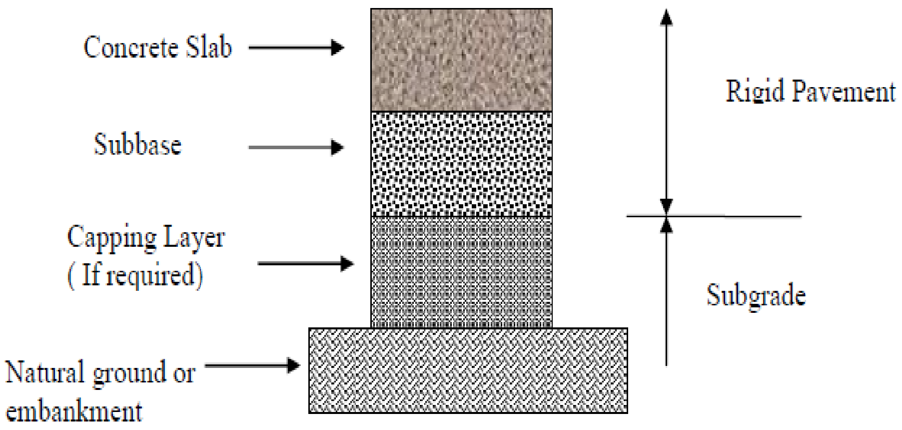


Figure: 2.2.3 Rigid Pavement Cross-Section

Minor variations in subgrade strength have little influence on the structural capacity of a rigid pavement. In the design of a rigid pavement, the flexural strength of concrete is the major factor and not the strength of subgrade. Due to this property of pavement, when the subgrade deflects beneath the rigid pavement, the concrete slab is able to bridge over the localized failures and areas of inadequate support from subgrade because of slab action.
Rigid pavements usually consist of a **sub-base** and **a concrete slab** but a capping layer is also used if required. When **the subgrade** is weak, the required thickness of material of sub-base quality required to protect the subgrade and to provide sufficient support for the concrete slab is substantial and it is usually more economical to provide a capping layer to perform part of the task, as shown in the

Any erosion of the sub-base layer under the concrete slab caused by the pumping action as traffic uses the road reduces the support to the concrete slab. This increases the tensile strains in the concrete itself and therefore the risk of cracking. In circumstances where this is likely it is recommended that the sub-base material is stabilised with cement or lime to provide support that is strongly resistant to erosion.

The sub-base is also required to provide a stable working platform on which to construct the concrete slab.
If the quality of the subgrade is acceptable, and if the design traffic is low (less than one million ESAs) a sub-base layer may not be strictly necessary between the prepared subgrade and the concrete slab. However, a sub-base layer makes it easier to achieve the required elevations within the specified tolerances and is usually recommended.

The concrete slab itself consists of Portland cement concrete, reinforcing steel (when required), load transfer devices and joint sealing materials.

For reinforced concrete pavements, transverse reinforcement is also provided to ensure that the longitudinal bars remain in the correct position during the construction of the slab. It also helps to control any longitudinal cracking that may develop.

2.5 Types of Rigid Pavements

There are three basic types of rigid pavement:

I. Jointed Unreinforced Concrete Pavements (JUCP)
II. Jointed Reinforced Concrete Pavements (JRCP)
III. Continuously Reinforced Concrete Pavements (CRCP)

I. Jointed Unreinforced Concrete Pavement

In Jointed Unreinforced Concrete Pavements (JUCP) the pavement consists of unreinforced concrete slabs cast in place and divided into bays of predetermined dimensions by the construction of joints. The dimensions of the bays are made sufficiently short to ensure that they do not crack through shrinkage during the concrete curing process. In the longitudinal direction the bays are usually linked together by dowels to prevent vertical movement and to help maintain aggregate interlock across the transverse joints. The bays are also connected to parallel slabs by tie bars, the main function of which is to prevent horizontal movement (i.e. the opening of warping joints).

II. Jointed Reinforced Concrete Pavement

In Jointed Reinforced Concrete Pavements (JRCP) the pavement consists of cast in place concrete slabs containing steel reinforcement and divided into bays separated by joints. The reinforcement is to prevent cracks from opening and this allows much longer bays to be used than for JUCP. The bays are linked together by dowels and tie bars as in JUCP. Although longitudinal reinforcement is the main reinforcement, transverse reinforcement is also used in most cases to facilitate the placing of longitudinal bars.

III. Continuously Reinforced Concrete Pavement

Continuously Reinforced Concrete Pavements (CRCP) are made of cast in place reinforced concrete slabs without joints. The expansion and contraction movements are prevented by a high level of sub-base restraint. The frequent transverse cracks are held tightly closed by a large amount of continuous high tensile steel longitudinal reinforcement.

2.6 Stress Development and Design Criteria

The concrete slabs in concrete pavements are subjected to two main types of stresses:

I. The stresses developed because of changes of the environment (moisture and temperature). These are related to the intrinsic properties of the concrete. In Ethiopia, although the annual range of temperature is small the daily range of temperature is high, varying from 20°C to 40°C. Therefore thermal stresses deserve special attention.

II. The stresses generated by the traffic.

The factors which control the performance of a rigid pavement and for which design criteria are required are as follows:

I. Quality of the concrete and steel for constructing the pavement slabs.
II. Strength of the subgrade.
III. Quality of the sub-base.
IV. Environment (moisture and temperature).
V. Traffic and design life.

2.7 AASHTO, Guide for Design of Pavement Structures 1993

The AASHTO design procedure for rigid pavement structural design, which is based on the AASHTO Road test pavement performance algorithm, is an empirical equation which is used to relate observed or measurable phenomena with outcomes.

The choice of each of the inputs used in the AASHTO Empirical equation for the Rigid Pavement Design is as explained below.

I. Modulus of sub grade reaction , k

Pavement support for rigid pavements is generally reduced to a k-value (an effective Modulus of sub grade reaction).

The design guide procedure for determining the effective Modulus of sub grade reaction value is rather complex based on the sub grade soil resilient modulus, considering the seasonal variation and then adjusting upwards and down wards for the sub base type and thickness, potential loss of support and presence of bed rock within 3.05 meters of depth below the surface.[AASHTO 1993].

The effect of all of these steps is a k -value usually fairly close to the original estimate. Loss of support should be avoided by using non-pumping materials under the slab, not by making the pavement thicker to compensate for weak support. In addition, in contrast to flexible or asphalt pavements, where thickness is highly dependent on the soil stiffness, for most concrete pavement design procedures, the thickness of the pavement is not very sensitive to the k-value.[Norbert Delatte]

Furthermore, the sub grade and sub base materials are more important as a construction platform and for protection of pumping than for determination of pavement thickness.

Hence, the k-value corresponding to the soil types [Hall et al. 1997: 80 and AASHTO 1998: 6] considering the type and thickness of sub base material and with some adjustments that suit the actual site condition is used for the thickness design.[Norbert Delatte].

II. Design Traffic ,W18

The cumulative traffic loading in the 40 years of design period, forecasted in the previous section, is about 114.97 million ESA.{**Table2.2.5** }.

Standard normal deviate (Z_R) and Combined standard error of the traffic prediction and performance prediction (S_o)

The standard normal deviator, ZR and Combined standard error of traffic prediction and performance prediction (So) are coefficients which represent the chosen reliability of a design. The concept of reliability is based on the assumption that the distribution of variables such as stress, resulting from uncontrollable factors such as loading and the environment ,and strength/stiffness of materials /layers resulting from controllable factors such as variations in construction quality and materials can be assumed to be of the normal distribution type. Reliability is the probability that the design will succeed for the life of the pavement.

The following ZR values are assigned for different reliabilities (the ASSHTO method)

Table 2.2.5. : - ZR values for intended reliability %ages.

Intended Reliability	Z_R	Intended Reliability	Z_R
99.99	-3.75	80	-0.841
99.9	-3.09	75	-0.674
99	-2.327	70	-0.524
95	-1.645	60	-0.253
90	-1.282	50	0
85	-1.037		

The following table from AASHTO 1993 pavement design manual recommended levels of reliability for various functional classifications.

Table 2.2.6 levels of reliability for various functional classifications.

Functional Classification	Recommended Level of Reliability			
	Urban		Rural	

Principal Arterials	80	– 99	75	– 95
Collectors	80	– 95	75	– 95
Local	50	– 80	50	– 80

Generally, as the volume of traffic, difficulty of diverting, and public expectation of availability increases (due to higher economic growth), the risk of not performing to the expectations must be minimized.

Hence, a standard deviation, So, of 0.35 and a reliability level of 90% is selected as recommended in the AASHTO design guide.

III. Difference between the initial design serviceability index, p_o, and the design terminal serviceability index, (ΔPSI)

A design initial serviceability index (Po) of 4.5 and design terminal serviceability index (pt) of was selected resulting in the difference (ΔPSI) to be 2.0.

IV. <u>Modulus of rupture of PCC (flexural strength), S'*c*</u>

Appropriate value was considered based on ACI suggestions.

V. <u>Drainage coefficient, Cd</u>

Different drainage coefficients, which represent the relative loss of pavement strength due to the total time a pavement structure is exposed to moisture levels approaching saturation and quality of drainage, are suggested in the AASTHO guide.

VI. <u>Load transfer coefficient , J</u>

The load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer (distribute) load across discontinuities, such as joints. A load transfer coefficient of 3.2 was used as is recommended in the AASTO 1993 pavement design guide for Plain jointed and jointed reinforced pavements without tied PCC shoulder.

VII. Elastic modulus of concrete, Ec

The elastic modulus of concrete (Ec), as for any type material, can be estimated from the following relationship:

$$E_C = 57{,}000\sqrt{f'_c}$$

Where: -

Ec = Portland cement concrete elastic modulus in psi and

F'c = Portland cement concrete compressive strength

As the compressive strength required for Portland cement concrete pavements is about 34.5 MPa (cylinder strength), the elastic modulus of concrete (Ec) can be computed using the above relationship.

VIII. Required Slab Thickness

Based on the above recommended inputs and adopting a reasonable reliability value considering the volume of traffic, difficulty of diverting, and the economic importance of the road, the thickness of the concrete slab required to carry future traffic was calculated iteratively using the AASHTO's basic design equation for rigid pavements.

The basic AASHTO Empirical Rigid Pavement Design Equation presented as follows is used to calculate the required slab thickness by an iterative procedure.

$$Log(W_{18})=Z_R*S_O+7.35Log(D+1)-$$

$$0.06+Log\frac{(\frac{\Delta Psi}{4.2*1.5})}{1+\frac{1.624*10^7}{(D+1)^{8.46}}})+(4.22+0.32Pt)log\{\frac{SC*Cd(D0^{0.75}-1.132)}{215.63\{D0.75-\frac{18.42}{(^{Ec}/_{k})0.25}}\}$$

Where:-

W18 = Predicted ESALs for the design period (40 years)

ZR = standard normal deviate for the desired reliability

So = combined standard error of the traffic prediction and performance prediction

D = slab depth (inches)

pt = terminal (final) serviceability index

ΔPSI = difference between the initial design serviceability index, po, and the design terminal serviceability index, pt

S'c = modulus of rupture of PCC (flexural strength)

Cd = drainage coefficient

J = Load transfer coefficient used to adjust for load transfer characteristics of a specific design

Ec = Elastic modulus of PCC

K = Modulus of sub grade reaction

Table 2.2.7 the required slab thickness in inches is found by iteratively solving the above equation for D and converted to mm.

Reliability Value selected	Slab thickness obtained using AASHTO (in mm)	Remark
90%	360	Recommended reliability
95%	377	
99%	409	

The road is the one and only access to Derba and other cement factories in the area and should serve well throughout the design life to satisfy the countries booming demands. However, some degree of deformation would be acceptable towards the end of the design period. Furthermore the longer design life of a concrete pavement will impose uncertainties in the performance of a pavement due to periodic maintenance shortage at the joints or the change in the dynamics of the traffic flow. Hence, an optimized slab thickness corresponding to a design reliability value of 90% was selected for the pavement structure.

I. Joint Spacing and dimensions

Joints in concrete pavements are placed to permit expansion and contraction of the pavement there by relieving stress due to environmental changes, friction, and to facilitate construction.

Pavement design manual recommends the joint spacing, S (ft) for plain concrete pavements should not greatly exceed twice the slab thickness, D (in inch) or S(mts)=0.024 D(mm). Hence, the maximum slab length shall be 30.14 ft (9.2 mts).[AASHTO 1993].

Provides a chart of maximum joint spacing as a function of pavement thickness and k- value. This is based on a maximum L/l ratio of 4.44, where L is the slab thickness and l is radius of relative stiffness calculated as follows.

$$\ell = \sqrt[4]{\frac{ED^3}{12(1-\upsilon^2)k}}$$

In the above equation E = the modulus of the elasticity of the concrete, D is the pavement thickness, k is the modulus of sub grade reaction, and v is the Poisson's ratio of concrete, typically taken as 0.15.

A maximum joint spacing of 5.4 mts is allowed for the slab thickness of 350mm and the assumed k value.[ACI Committee 325 (2002: 14)].

For the subject project, considering the minimum variation in diurnal temperature on one hand and the steep grade in some sections of the selected stretch an optimum slab length of 5 meters is recommended for the JUCP type pavements.

II. <u>Dowel Bar diameter and dimensions</u>

Dowel bars should be used on all routes carrying more than a low volume of heavy trucks. The purpose of dowels is to transfer loads across a joint without restricting joint movement due to thermal contraction and expansion of the concrete .Dowels are used to prevent pumping and faulting.

A guide recommends a dowel diameter of 1/8 times the slab thickness and a dowel spacing and length of 12 inches (305 mm) and 18 inches (457 mm) respectively [AASHTO design].

For highway pavement, America's Federal high way Authority recommends the minimum dowel diameter to be D/8, where D is the thickness of the pavement [FHWA 1990a].

Dowels should be corrosion-resistant to prevent dowel seizure, which causes the joint to lock up. Epoxy-coated and stainless steel dowels have been shown to adequately prevent corrosion.

Table 2.2.8 Dowel bar diameter recommendations by the American Concrete Institution is presented in the table below [ACPA 1998: 27, ACI Committee 2002 325: 15].

Slab thickness, mm (in)	*Dowel diameter, mm (in)*	*Dowel length, mm (in)*	*Dowel spacing, mm (in)*
<200 (<8)		Dowels not required	
200 (8)	32 (1.25)	450 (18)	300 (12)
250 (10)	32 (1.25)	450 (18)	300 (12)
280 (11)	38 (1.5)	450 (18)	300 (12)
300 (12)	38 (1.5)	450 (18)	300 (12)
350 (14)	44 (1.75)	500 (20)	300 (12)
400 (16) and up	50 (2)	600 (24)	450 (18)

III. Reinforcement Design (for reinforced concrete pavements)

AASHTO 1993 pavement design guide, the purpose of distributed steel reinforcement in reinforced concrete pavement is not to prevent cracking but to hold tightly closed any cracks that may form, thus maintaining the pavement as an integral unit .

For longitudinal and transverse steel reinforcement design of a jointly reinforced concrete slabs, AASHTO 1993 design manual recommends the use of a monograph which takes the slab length, steel working stresses and friction factor based on the type of material beneath the slab into account.

Using a slab length of 15 meters, a steel working stress of 45,000 psi for Grade 60 reinforcement bars and a friction factor of 1.2, the percentage of steel reinforcement required is computed to be 0.066% .If slab length is increased to 20 meters to reduce frequency of joints the required percentage of steel reinforcement will be 0.088.

I. Technical Comparison

Comparison of the alternative pavement structures: one obtained by the ERA's -2013 pavement design manual and the other adopting the AASHTO's 1993 design guide, it is observed that both manuals provide a reasonably similar thickness of 350 and 360 mm thick JUCP respectively when C-40 concrete is used.

ERA's 2013 PDM volume II provides an option for usage of C35 and C-30 concretes for rigid pavements in addition to the C-40 concrete class.

Among the two types of concrete pavement structures discussed in section 4.3.1 Jointed Unreinforced and Jointed Reinforced, (JUCP and JRCP); the Jointed Reinforced Concrete Pavement (JRCP) type pavement is selected for the following reasons

-JRCP is suitable for all levels of traffic and is used when the risk of settlements of the sub grade cannot be neglected. From the experience of the work man ship of the Contractor it is noted that the risk of the sub grade settlement cannot be neglected.

- Less concrete is required if there is more reinforcement
- Less maintenance is required if there are fewer joints
- Riding quality will be better than JUCP because of the rather distant joint spacing.

As per the newly released ERA's 2013 PDM Volume II is JRCP (25 meters long slab) and.

II. Pavement Materials Specification

Sub grade, Embankment Construction and Sub-base Materials

In order to be consistent with the works contract of the project, the current material specifications of the project for the Sub grade, Embankment Construction Materials and Sub-bases shall be applied.[ERA 2002technical specification]

Capping layer material shall have a minimum CBR of 15% at the highest anticipated moisture content.

Material for Concrete Pavement

Material for concrete shall meet the requirements of Division 7102 of ERA's 2002 Technical specification with minor adjustments as follows:

(a) **Water**: in addition to requirements of division 7102, water to be used for concrete shall confirm the requirements of division 8402(d) of ERA's -2002 technical specification.

(b) Concrete aggregate:

Add the following sentence at no 6 of (ii) coarse aggregates:

The maximum aggregate size of coarse aggregate shall be 25 mm and the gradation of concrete coarse aggregates shall meet either of the options presented in the following table extracted from Table 7100-2, Gradation for Coarse Aggregate of ERA's 2002 specification

Table 2.2.9 Gradation for Coarse Aggregate of ERA's 2002 specification

Test sieve (mm)	Percentage by mass of total aggregate passing test sieve
	Nominal size 25 mm
50 37.5	100 100
25	95-100
19	
12.5	25-60
9.5	
4.75	0-10
2.36	0-5

(c) Materials for Joints

Add the following paragraph at the end:

A hot mixture of one part by volume of fine sand and three part by volume of 80/100 bitumen can also be used to fill the joints.

(d) Separation Membrane

Add the following paragraph at the end:

MC-30 prime coat material with an application rate of 1.2-1.5 liters per meter square can also be used as a separation membrane between the sub base layer and the concrete slab.

(e) Concrete Requirements

By Proportioning Replace paragraph three by:

Concrete Strength- the mix shall be designed to produce concrete with a minimum job average compressive strength of 35 MPa and a flexural strength of 3.5 MPa at 28 days.

CHAPTER THREE

CASE-STUDY: ANALYSIS AND DISCUSSION

3.1 Brief Description of the Project Area

The project road is located in Oromia Regional State. The project road starts at Chancho town (472670E, 1028063N) at a distance of 38km from Addis Ababa on the main Addis Ababa – GohaTsion road. The project road terminates at Becho (326646E, 1480877N) near Derba cement factory area with additional 2.3km spur road from Derba junction to Muger Cement quarry passing through Derba village. The elevation of the road is around 2614m above sea level at Chancho, 2384m above sea level at Derba, 2370m above sea level at Factory Site and around 1498m above sea level around the mining area.

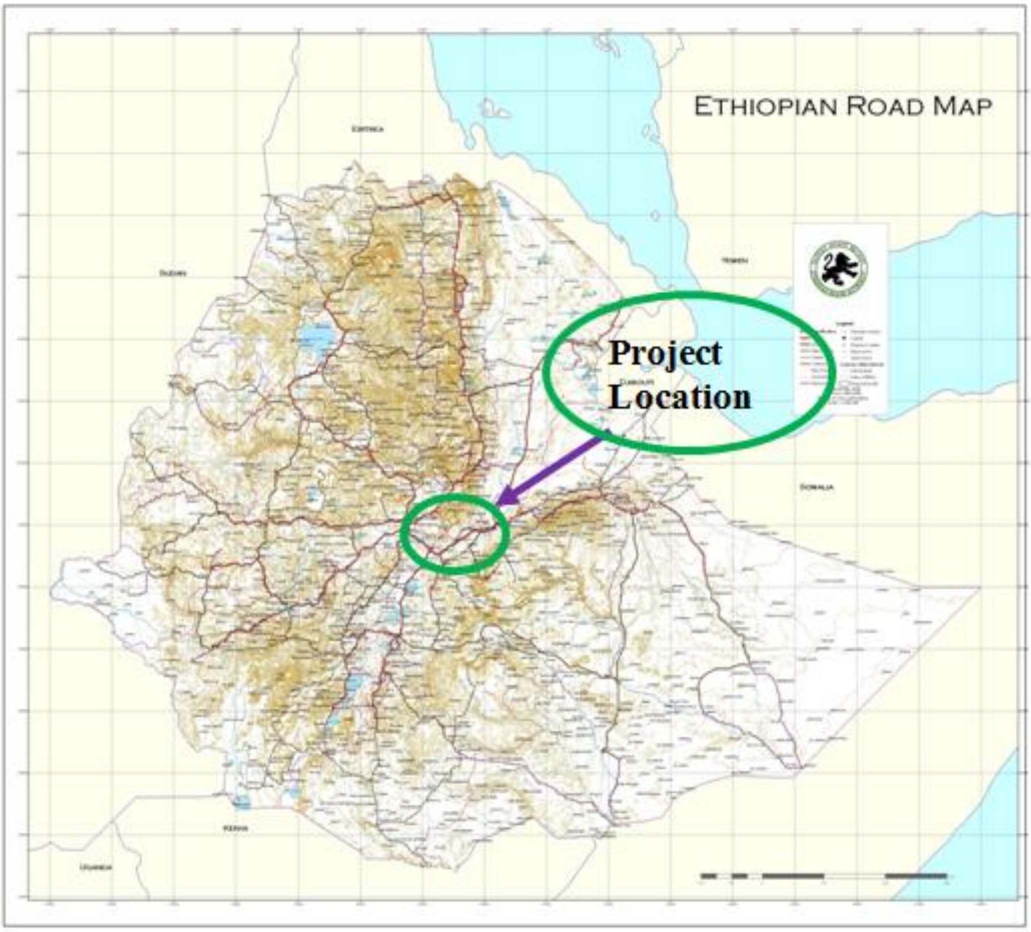


Figure 3.1 Project Location Map within country

3.2 Geology

The geologic formation of the project area is assessed based on the Geologic Map of Ethiopia 1996 edition and observations made during the site visit. Thus, the project area is dominantly covered with Aiba basalts.

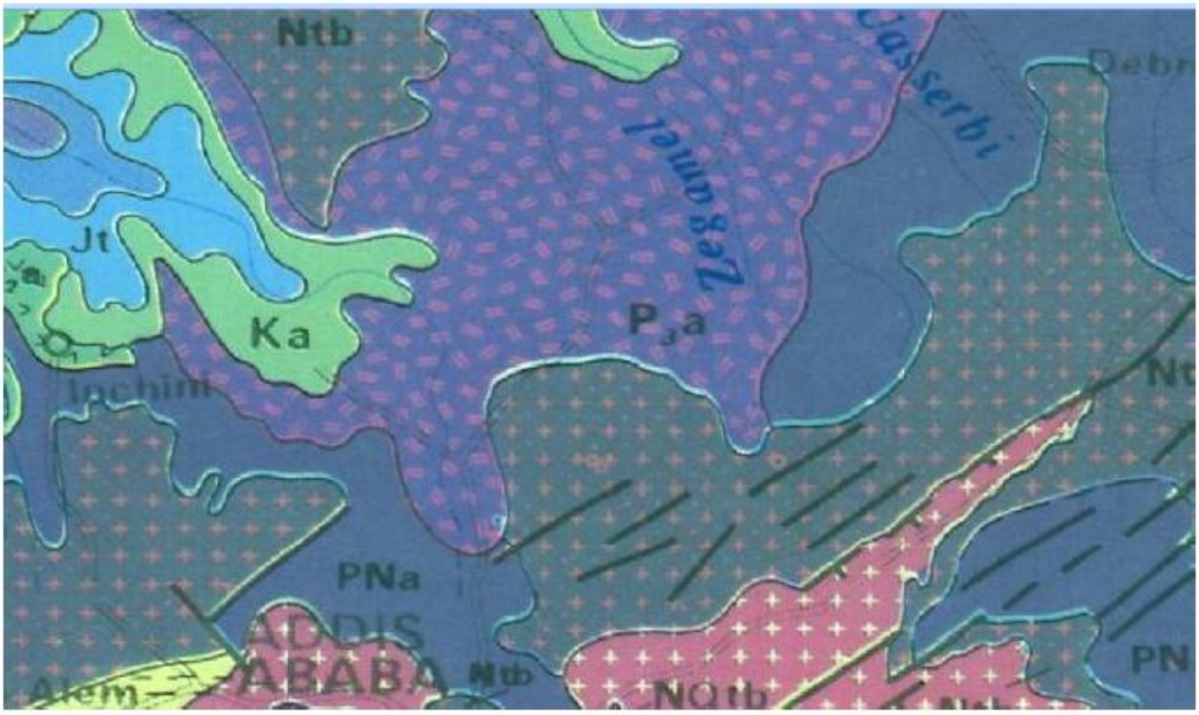


Figure3.2Geological Map of the Project Area

The Aiba basalts / P3a represent the second pulse of fissural basalt volcanism on the North West plateaus. These are generally aphynitic in nature and rocks stratification contains rare interbedded basic tuffs. They cover the entire route corridor.

3.3 Climate

The area through which the project road traverses can be classified as “WeinaDega” with the altitude ranging from 2300 to 2600m above sea level.

3.4 Temperature

The mean monthly minimum and maximum temperature of the project area is assessed by referring to the Meteorological Map of Ethiopia. Accordingly, the mean monthly minimum and maximum temperatures are 5 & 200C, respectively.

Table 3.4-1 Mean monthly maximum and minimum temperatures for the project area are summarized.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAT
Max.	20	20	20	20	20	20	20	15	15	20	20	20	**20**
Min.	5	5	10	10	10	10	10	10	10	5	5	5	**8**

3.5 Rainfall

Rainfall data of the project area has been obtained, similar to the temperature data, from the Meteorological Map of Ethiopia. Accordingly, the monthly rainfall varies from 25mm December to 400mm in July and August and the annual rainfall is 1335mm.

Table 3.5-1 Mean Monthly and Annual Rainfall (mm)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Rainfall (mm)	25	25	50	50	50	100	400	400	150	50	25	10	**1335**

3.6 Soils and Materials Investigation

The stretch between km 8+100 to Km 18+000 is selected for the introduction of the 10 km long rigid pavement. The terrain of the selected stretch is dominated by undulating terrain having gradients to 8%.

For the selected stretch, the following data collected during the detailed design period is used for the rigid pavement structure design.

3.7 Sub Grade Soil extension

The soil extension survey in the proposed section is as follows

Table 3.7-1 Soil extension survey km 9+100 - 18+000

Station (km)	Material Description	Remark
9+100 – 9+900	Dark brown silty clay soil sometimes underlain by weathered and fractured rock	
9+900 – 11+400	Dark clay	Expansive
11+400 – 11+940	Dark grayish silty clay soil	Expansive
11+940 – 13+800	Brownish silty clay soil sometimes overlain by basaltic boulders, cobbles and gravels	
13+800 – 17+500	Dark clay	Expansive
17+500 – 18+870	Brown to reddish brown silty clay soil	

3.8 Test results of Sub Grade Material

The following table presents the test results of the sub grade material in the selected stretch, Km 9+100 – 18+000

Table 3.8-1 Summary of the test results of subgrade materials

Station (km)	% passing 0.075mm sieve	LL	PI	AASHTO Soil Classification	CBR at 95% MDD	Swell %
9+200	88	57	19	A-7-5(22)	12	1.7
9+700	85	76	37	A-7-6(38)		_
10+600	94	80	37	A-7-5(45)		_
11+000	91	66	28	A-7-5(32)	10	2.5
11+500	88	72	30	A-7-5(34)		_
12+000	95	72	31	A-7-5(38)	6	2.6
12+500	92	53	19	A-7-5(22)		_
13+000	76	54	18	A-7-5(16)	4	2.0
13+500	85	50	19	A-7-5(19)		_
14+000	91	72	33	A-7-5(38)	3	3.0
14+500	92	68	28	A-7-5 (33)		
15+000	80	48	15	A-7-5(14)	11	1.8
15+000	86	77	36	A-7-5(38)	2	3.1
15+500	93	69	30	A-7-5(36)		_
16+000	94	68	25	A-7-5(32)	3	3.0
16+500	97	92	48	A-7-5(60)		_
17+000	90	66	28	A-7-5(32)	2	2.3
17+500	92	50	17	A-7-5(20)		_
18+000	90	51	17	A-7-5(19)	15	1.6

From table 3.8-1 above it is observed that almost all the sub grade soils in the selected stretch falls in group A-7-5 AASHTO classification, except the soil at km 9+700. As per AASHTO specification, AASHTO-M145, all the sub grade soils in the stretch are rated as poor sub grade materials.

A design sub grade CBR of 2.5% ,which was obtained for the stretch between km 0+000 – km 18+700 (homogeneous section-1) during the detail engineering design of the road is considered for the selected nearly 10 km long stretch.

Excessive differential shrink and swell of expansive soils cause non- uniform sub grade support. As a result, concrete pavements may become distorted enough to impair riding quality. Several conditions can lead to this pavement distortion and warping:

I. If expansive soils are compacted when too dry or are allowed to dry out prior to paving, subsequent expansion may cause high joints and loss of crown.
II. When concrete pavements are placed on expansive soils with widely varying moisture contents, subsequent shrink and swell may cause bumps, depressions, or waves in the pavement.

III. Similar waves may occur where there are abrupt changes in the volume change capacities of sub grade soils.

Hence, in order to reduce settlement of the weak sub grade material, removal of the unsuitable sub grade material and replacement by approved borrow material for a minimum thickness of 1000 mm shall be done to improve the sub grade CBR. In addition, proper placing and compaction procedure shall be followed to make sure that the foundation layer stays stable during the design life of the pavement.

3.9 Rigid Pavement Design

The pavement design the project is done based on the traffic flow pattern, composition and loading.

The traffic study and analysis used for the design of the pavement structure with flexible pavement standard was used to determine the traffic loading on the introduced rigid pavement throughout the proposed design life.

Rigid pavements are very strong in compression; the strength of the pavement is contributed mainly by a concrete slab, unlike flexible pavements where successive layers of the pavement contribute cumulatively. This nature of rigid pavements has made feasible their design for a longer life, up to 60 years. For the introduction of the rigid pavement in the project road a design life of 40 years is done as per ERA-2013 pavement design manual volume II.

Traffic forecasting, by its very nature, is generally a highly uncertain undertaking in developing countries like Ethiopia. In cases such as this where the road section is to be designed for 40 years of service life, it becomes very difficult, if not impossible, to accurately estimate the rate of growth, dynamics of changes in the economy and the traffic modal changes. However, as the route will be dominantly used by the Derba and other cement factories in the area reasonable assumptions were made based on the factories future production plan and it is tried to estimate the design traffic based on the reality of the foreseeable future.

Pavement design, in general, is a process of selection of appropriate pavement and surfacing materials to ensure that the pavement performs adequately and requires minimal maintenance under the anticipated traffic loading for the proposed design period. This selection process involves adoption of material types, thicknesses and configurations of the pavement layers to meet the design and performance objectives.

The introduction of the 10 kilometre rigid pavement in the subject project has the following advantages:

- It is feasible to design rigid pavements for longer design life
- It will be an experience for the country

- It will avoid/minimize importing of construction materials like Bitumen by use of locally available materials,

- The project route is expected to be exposed to severe traffic loading in the near future as the cement factories in the area will start production in their full capacity. Hence, the introduction of the rigid pavement will avoid/reduce unavoidable recurrent maintenance requirements had the selected section been constructed of flexible pavement structure.

The specifications of the pavement construction materials were set to conform to the project condition and the requirement of the design manual used for the design of the pavement structures.

3.10 Traffic Surveys and Analysis

The trend and pattern of the traffic flow of the project area were assessed and analysed with due consideration of the future generated traffic in the original design period using ERA's traffic count formats.

The design traffic or the cumulative Equivalent Standard Axle of 8.16 ton is derived from the total number of heavy vehicles during the design life of the road converted to ESA using the following equivalence factor.

$$\text{Equivalenc e Standard Axel Load Factor} = \left(\frac{AL(kg)}{8160}\right)^4 *$$

From the newly released ERA's Manual 2013 suggests a power of 4.3 for the determination of Equivalence Standard Axel Load Factor (ef), however the previously computed equivalency factor, ef, with the power of 4 was utilized considering the small variation and urgency of the works.

Based on this relationship and using the axle load data obtained from the survey the equivalence factors are derived. The damage caused by light vehicles such as cars, Land Rovers and Small buses are insignificant compared to the other commercial and heavy.

Vehicles and hence not included in the cumulative equivalent standard axle load for pavement design. As mentioned earlier traffic projections for such a long period, 40 years, presents many uncertainties. However, as the number of Track and Trailers which will dominate the road can be estimated with reasonable accuracy from the out puts of the factories the expected loading of the road for the proposed design period is estimated as presented below.

Finally the Truck and Trailer group is assumed to double for the last 15 years in consideration.

The opening year of the road is assumed to be 2015 owing to the volume of works due to the change of pavement type.

Table 3.10-1 the projected traffic volume over the design period and the corresponding ESA

Year	Cumulative ESA	Year	Cumulative ESA
2015	1,263,856	2035	39,760,746
2016	2,536,457	2036	41,998,582
2017	3,818,572	2037	44,259,920
2018	5,111,595	2038	46,546,226
2019	7,007,917	2039	50,631,014
2020	8,917,249	2040	54,743,530
2021	10,840,335	2041	58,884,516
2022	12,778,881	2042	63,055,712
2023	14,734,286	2043	67,258,524
2024	16,705,112	2044	71,481,992
2025	18,692,094	2045	75,726,162
2026	20,696,632	2046	79,991,731
2027	22,720,126	2047	84,279,396
2028	24,764,042	2048	88,589,826
2029	26,829,819	2049	92,923,783
2030	28,919,761	2050	97,282,006
2031	31,035,374	2051	101,665,188
2032	33,178,754	2052	106,074,035
2033	35,352,004	2053	110,509,250
2034	37,545,676	2054	**114,971,528**

3.11 Design Traffic [DT]

Design Traffic is the number of equivalent standard axle expected within the design period of the road (40 years). For the selected stretch, the design traffic for a 40 years design period (At the end of 2054) as computed in the above table is **114.97** million ESA.

Design of Pavement Structure

The pavement structure was designed using ERA's 2013 pavement design manual volume II: Rigid Pavements and AASHTO's 1993 Guide for design of pavement structures. Both methods are discussed in detail as follows.

Depending on the presence/level of reinforcement, the newly released ERA's 2013 Pavement Design Manual: Volume II Rigid Pavements categorizes the rigid pavements into three basic types:

In this project the JRCP type of rigid pavement structure is used

In Jointed Reinforced Concrete Pavements (JRCP) the pavement consists generally in a cast in place concrete slab divided in reinforced concrete bays separated by joints. The reinforcement is made to prevent developing cracks from opening. This allows designing of much larger bays JRCP than with JUCP. The bays are linked together by tie bars to prevent horizontal movement and thus ensure load transfer through aggregate interlock. The longitudinal reinforcement is the main reinforcement. A transverse reinforcement in most cases is usually added to facilitate the placing of longitudinal bars.

The sub grade material strength is not satisfactory; with the in-situ sub grade CBR value of 3% for the selected ~10Km stretch. Hence, as discussed earlier (section 3-3 above) replacement of the unsuitable sub grade material shall be done up-to 1000 mm depth to get a design subgrade CBR of 7%.The sub grade class will be S3.

Therefore, considering a design sub grade class of S3, a 250 mm thick capping layer as indicated in Table 6-2, page 6-4 of ERA's 2013 Pavement design manual volume II is required for both pavement types; JRCP and JRCP.

The capping layer material shall be selected material which will be used both as a replacement for the weak sub grade material and as a separating membrane to avoid upward migration of fines from the sub grade material (A-7-5) towards the slab causing pumping at joints and slab edges.

In addition to the provision of a capping layer, a sub base thickness of 185 mm for JRCP and 200 mm for JUCP pavements (as indicated in tables 6-2, 6-3 and 6-4 of ERA's 2013 Pavement design manual: volume II) is provided in order to prevent "pumping" at joints and slab edges, to provide a stable "working platform" for the construction equipment and to facilitate the achievement of surface levels with the required tolerances.

3.12 Concrete Slab Thickness, Joints and Reinforcement Design

I) Jointed Unreinforced Concrete Pavements (JUCP)

According to ERA's 2013 Pavement design manual volume II (page 6-6, figure 6-

2(a)) a plain concrete with thickness of

- 350 mm if C-40 concrete is used
- 380 mm if C-35 Concrete is used and
- 415 mm if C-30 Concrete is used, is required for a cumulative ESA. of 114.97 million expected in the 40 years design life for a JUCP without tied shoulders.

Transverse joints shall be provided at every 5mts interval. Load transfer between adjacent bays is provided by dowels. The dowels shall be 400 mm long and 25 mm in diameter and shall be placed at 300mm spacing.

Longitudinal joints shall be placed at the edge of each traffic lanes. Tie bars shall be provided for all longitudinal joints at a spacing interval of 600 mm. The tie bars shall be 1000 mm long and 12 mm in diameter.

Construction joints, especially when the concrete is stopped, shall be coupled with other joints.

II) Jointed Reinforced Concrete Pavements (JRCP)

The ERA's 2013 PDM volume II suggests different concrete slab thicknesses for a JRCP pavement based on the anticipated traffic, the amount of reinforcement and the concrete grade selected.

For the expected commutative traffic of 114.97 million ESA the following thicknesses were obtained from the manual. The Slabs are without tied shoulders.

TABLE 3.11-1:- Summary of Jointly Reinforced Rigid pavement design

Pavement Type	Jointed Reinforced Concrete Pavements (JRCP) Longitudinal Reinforcement of			
	500mm2/m	600mm2/m	700mm2/m	800mm2/m
Design Traffic	114.97 million ESA ,40 years of design life			
Capping Layer thickness	**250 mm**			
Sub Base thickness	**185 mm**			
Concrete Thickness **(C-40)**	320 mm	300 mm	290 mm	280 mm
Concrete Thickness **(C-35)**	360 mm	340 mm	320 mm	310 mm
Concrete Thickness **(C-30)**	400 mm	375 mm	360 mm	340 mm

TABLE 3.11-2:- Summary of Jointly Reinforced Rigid pavement design

pavement Type	Jointed Reinforced Concrete Pavements (JRCP) Longitudinal Reinforcement of			
	500mm2/m	600mm2/m	700mm2/m	800mm2/m
Longitudinal Reinforcement	Ø14mm @ 300 mm spacing	Ø14mm @ 250 mm spacing	Ø14mm @220 mm spacing	Ø14mm @ 190mm spacing
Transversal Reinforcement	12 mm steel bars @ 600 mm spacing			
Spacing of Transversal Joints	25 meters*			
Dowels for transversal joints	25 mm diameter plain bars 400 mm long @ 300 mm spacing			
Tie bars for longitudinal joints	1000 mm long ,12mm diameter reinforcement bars @600 mm spacing			

In addition to the longitudinal reinforcement a transverse reinforcement of 12 mm diameter steel bars at 600 mm spacing shall be provided.

As per ERA's-2013 PDM, Volume II rigid pavement manual, transverse joints shall be provided at every 25mts interval.

Load transfer between adjacent bays is provided by dowels. The dowels shall be 400 mm long and 25 mm in diameter and shall be placed at 300mm spacing.

Longitudinal joints shall be placed at the edge of each traffic lanes. Tie bars shall be provided for all longitudinal joints at a spacing interval of 600 mm. The tie bars shall be 1000 mm long and 12 mm in diameter.

Construction joints, especially when the concrete is stopped, shall be coupled with other joints.

The summary of concrete pavement structure without tied shoulders obtained by ERA's 2013 pavement design manual volume II, for the design life of 40years with a cumulative ESA. of 114.97 million, is presented in the following table.

TABLE 3.11-3:- Summary of Rigid pavement design according to ERA 2013 PDM V-II

pavement Type	JUCP	Jointed Reinforced Concrete Pavements (JRCP) Longitudinal Reinforcement of			
		500mm2/m	600mm2/m	700mm2/m	800mm2/m
Design Traffic	114.97 million esa ,40 years of design life				
Capping Layer thickness	250 mm	250 mm			
Sub Base thickness	200 mm	185 mm			
Concrete Thickness **(C-40)**	350 mm	320 mm	300 mm	290 mm	280 mm
Concrete Thickness **(C-35)**	380 mm	360 mm	340 mm	320 mm	310 mm
Concrete Thickness **(C-30)**	415 mm	400 mm	375 mm	360 mm	340 mm
Longitudinal Reinforcement	-	Ø14mm @ 300 mm spacing	Ø14mm @ 250 mm spacing	Ø14mm @220 mm spacing	Ø14mm @190mm Spacing
Transversal Reinforcement	-	12 mm steel bars @ 600 mm spacing			

pavement Type	JUCP	Jointed Reinforced Concrete Pavements (JRCP) Longitudinal Reinforcement of			
		500mm2/m	600mm2/m	700mm2/m	800mm2/m
Spacing of Transversal Joints	5 meters	25 meters*			
Dowels for transversal joints	ф25 mm plain bars 400 mm long @ 300 mm	25 mm diameter plain bars 400 mm long @ 300 mm spacing			
Tie bars for longitudinal joints	1000 mm long ,12mm diameter reinforcement bars @600 mm spacing	1000 mm long ,12mm diameter reinforcement bars @600 mm spacing			

The project pavement structure is Jointed Reinforced Concrete Pavement (JRCP). It should be noted that the pavement structural design and subsequent choice of the JRCP type pavements was based on the improvement of the otherwise weak sub grade soil in the stretch and the surface dressing of the shoulder, as in the original pavement design, to control moisture ingress towards the sub grade soil.

Emphasis should also be made here that the performance of concrete pavements heavily depends on the concrete mix quality, materials used, the quality of workmanship and proper curing as on its adequate thickness and the level of the sub grade support.

ERA’s 2013 Pavement design manual volume II states “The main disadvantage compared to a flexible pavement is that if a rigid pavement is not properly constructed it tends to be more troublesome and reconstruction or repair can be more difficult”.

Hence, it is imperative that the contractor uses proper machinery, material, procedures and workmanship for the preparation of the concrete mix design and the construction of the rigid pavement works.

C-35 concrete is applied in this project because it can be consistently attained.

TABLE 3.11-4:-The project pavement structure is a Jointed Reinforced Concrete Pavement (JRCP) with the pavement structure shown below.

Pavement Type	Jointly Reinforced Concrete Pavement (JRCP)
Design Traffic	114.97 million esa ,40 years of design life
Replacement of unsuitable sub grade material	Minimum of 600 mm depth below capping layer
Capping layer thickness	250 mm
Sub Base Layer thickness	185 mm
Designed concrete slab thickness	340 mm (34cm)
Concrete Class	C-35
Longitudinal reinforcement	25 meters
Spacing of Transversal Joints	600 mm^2/m
Transversal Reinforcement	12 mm diameter at 600 mm spacing
Dowels for transversal joints	25 mm diameter plain bars 400 mm long @ 300 mm spacing
Spacing of Longitudinal Joints	3.5 meters (center line of the road, at the edge of each traffic lane)
Tie bars for longitudinal joints	1000 mm long ,12 mm diameter reinforcement bars @600 mm spacing

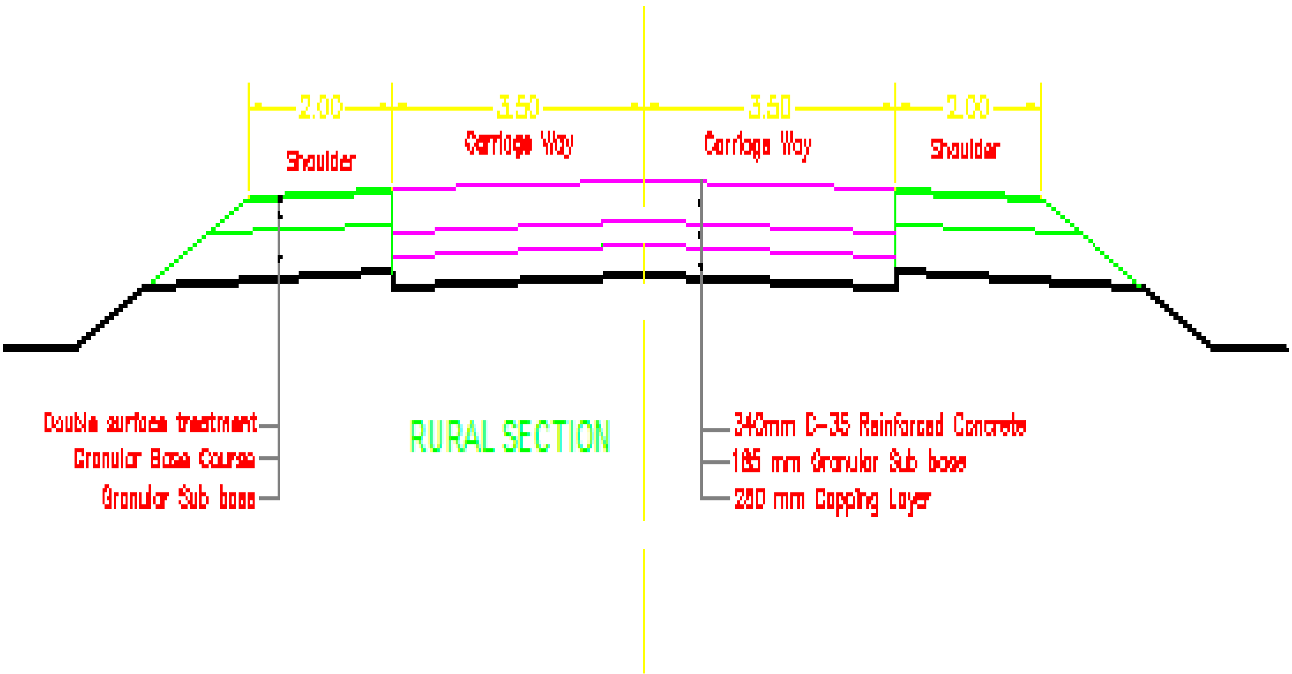


Figure3.3: Rigid pavement Cross-section

3.13 Flexible Pavement Design

The cumulative number of equivalent standard axles over the design period is by far greater than the maximum limit of 30 million ESA of ERA Pavement Design Manual 2002. Thus, reference has been made to the Indian Roads Congress 2001 manual that has structural catalogues for design traffic up to 150 million ESA.

The pavement designs given in the previous versions of IRC were applicable to design traffic up to 30 million standard axles (msa). With the increasing traffic and incidence of overloading, arterial roads need to be designed for traffic far greater than 30 msa. As empirical methods have limitations regarding their applicability and extrapolation, the analytical method of design has been used to reanalyse the existing designs and develop a new set of designs for design traffic up to 150 msa making use of the results of pavement research work done in the country and experience gained over the years on the performance of the existing designs.

Design Approach and Criteria

Based on the performance of existing design and using analytical approach, simple design charts and a catalogue of pavement designs have been added for use of field engineers. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 350C. The layer thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

I. Design traffic in terms of cumulative number of standard axles and
II. CBR value of subgrade

The project road is delineated in to two homogeneous sections based on the subgrade strength: section 1 with a design CBR of 7% and section 2 with a design CBR of 11%. The design traffic of the project road is 92msa which is close to 100 msa.

TABLE 3.11-5:-The pavement design catalogues for design CBR values of 7% and 10% and design traffic in the range of 10 – 150 msa are shown in the figures below.

PAVEMENT DESIGN CATALOGUE
PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 7%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	580	40	60	Base = 250 Sub-base = 230
20	610	40	90	
30	630	40	110	
50	650	40	130	
100	675	50	145	
150	695	50	165	

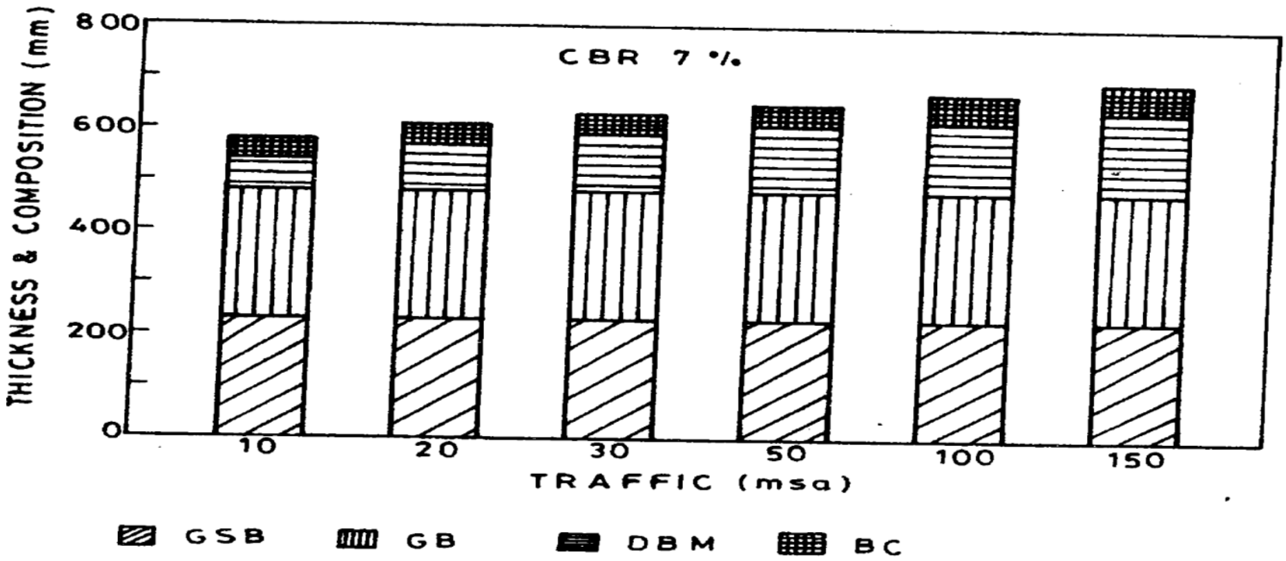


Figure 3.11-6 IRC Design catalogue for design CBR of 7% and design traffic of 10 – 150 msa

PAVEMENT DESIGN CATALOGUE

PLATE 2 – RECOMMENDED DESIGNS FOR TRAFFIC RANGE 10-150 msa

CBR 10%				
Cumulative Traffic (msa)	Total Pavement Thickness (mm)	PAVEMENT COMPOSITION		
		Bituminous Surfacing		Granular Base & Sub-base (mm)
		BC (mm)	DBM (mm)	
10	540	40	50	Base = 250 Sub-base = 200
20	565	40	75	
30	580	40	90	
50	600	40	110	
100	630	50	130	
150	650	50	150	

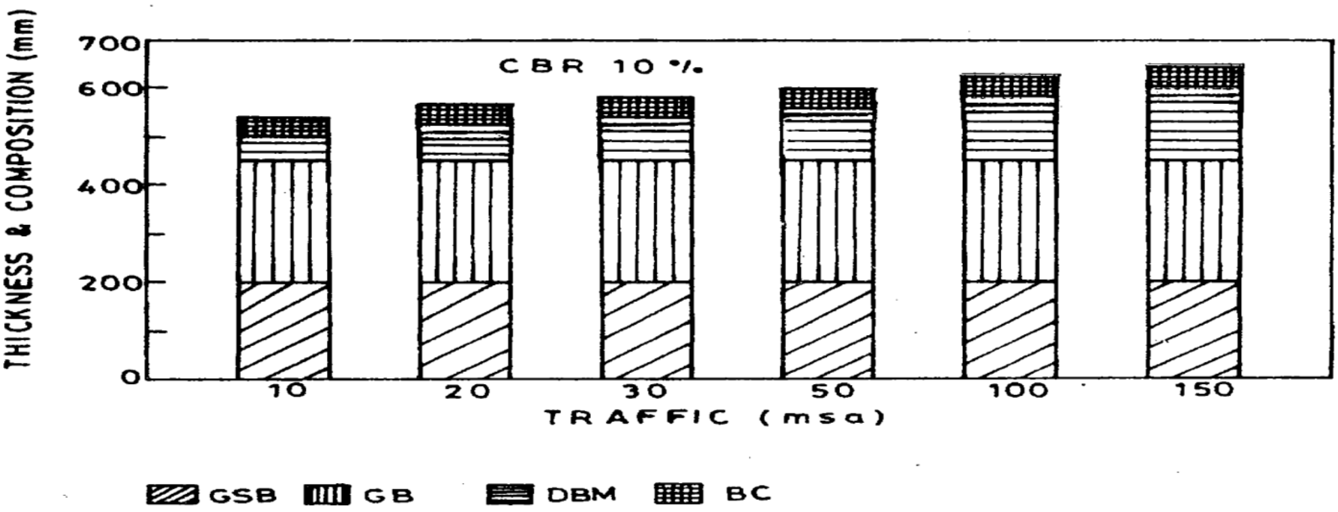


Figure 4.2IRC Design catalogue for design CBR of 10% and design traffic of 10 – 150msa

The pavement layer thicknesses that correspond to the design traffic and the design subgrade strength are summarized and presented in the table below.

TABLE 3.11-5:-Pavement Layer Thicknesses

	Design CBR (%)	Design Traffic (msa)	Pavement layer thickness (mm)			
			AC	DBM	BC	SB
Section 1	7	92.5	50	145	250	230
Section 2	11	92.5	50	130	250	200

For Section 1: km0+000 -18+700, km*18+700-*21+000

For Section 2: km18+700 - 28+830

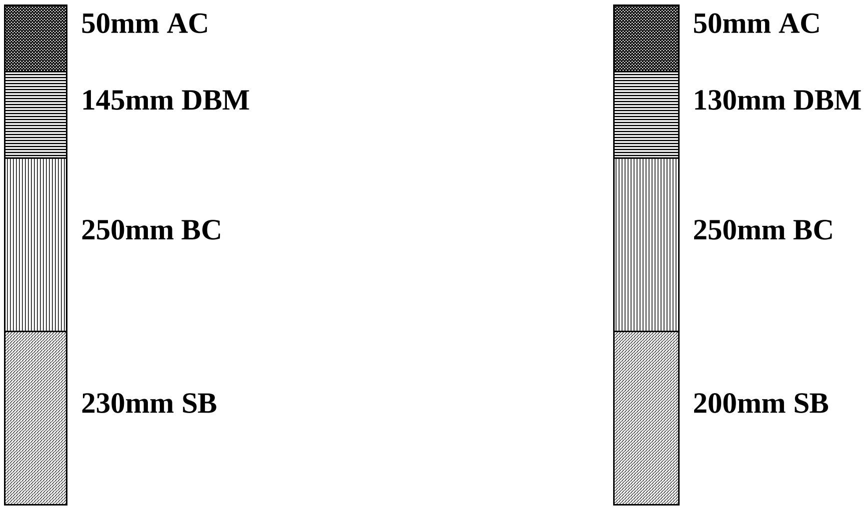


Figure 4.3 Pavement structures for the project road.

CHAPTER FOUR

COST COMPARISON OF THE RIGID AND FLEXIBLE PAVEMENT

4.1 Cost Estimate for the 10km rigid pavement for the selected stretch, Km 8.0 to Km 18, Jointed Reinforced Concrete Slabs with 600mm2/m reinforcement.

The estimated amount of materials required for the variation work due to the change in the pavement type and the corresponding estimated costs are presented in the following table. The items are presented as per the payment items listed in Division 7123 of ERA's 2002 specification. An additional item, a separation membrane, which is listed in Division 7113, was added in the list as it is required in the work.

The cost of the shoulder construction is not included as the original design is adopted

Note: The Comparison is based on cost estimates using the following unit rates

I. Gravel Sub Base- 184.1Birr/m3- The agreed Rate from the BOQ item of the project, as there is no change in the nature of the work and only minor change in quantity

   C-35 Concrete= 4,194.34 Birr/m3 – estimated cost, C-40 unit rate= 4329.07 Birr/m3

II. Reinforcement and dowel bars- 52.31 Birr/kg rate is taken for Rigid pavement Construction project

III. Separation membrane - 40.09 Birr/m3 -The agreed Rate from the BOQ item of the project, as there is no change in the nature of the work and minor change in quantity

TABLE 4.1-1 Estimated Cost and Quantity of Materials for the 10Km long Reinforced concrete rigid pavement at km 8+00 – 18+000

Item No	*Description*	*Unit*	*Quantity*	*Rate*	*Amount in Birr*
4200	**ROAD WAY AND BORROW EXCAVATION**				
42.01(b)ii	**Capping Layer** compacted to 95% MDD,AASHTO T-180	m3	19,966.40	113.39	***2,263,990.10***
5100	**SUBBASE**				
51.01 (a)i	Gravel Sub-base layer,97%MDD,AASHTO T-180	m^3	12,937.40	184.1	***2,381,775.34***
7000	**: RIGID PAVEMENT**				
7100	**Concrete Pavement**				
	Concrete Trial Pavement				
71.01(a)	**Manual Construction**	m2	300	1,426.08	***427,824.00***
71.01 (b)	Concrete Pavement 340 mm thick (C-35 71.2 concrete with flexural strength of 3.5 mpa at 28 days for the concrete slabs, keys at 39 locations and end detail shown in the drawings) (mechanical Construction	m2	60	1,426.08	***85,564.80***
71.02 (b)	Concrete Pavement 340 mm thick (C-35 concrete with flexural strength of 3.5 mpa at 28 days for the concrete slabs, keys at 39 locations and end detail shown in the drawings) (mechanical Construction		70,027.80	1,426.08	***99,865,245.02***
	71.4 Texturing and Curing the Concrete pavement				***0.00***
	Burlap dragged and / or grooved texture	m2	69,931.90	10	***699,319.00***
71.04(b)	Curing	m2	80,064.20	60	***4,803,852.00***
71.6	**Joints**				***0.00***
71.06(a)	Expansion Joint complete (except Dowels and end caps)	m	14	284.28	***3,979.92***
71.06(b)	Longitudinal joints complete (except tie bars	m	9,933.70	23.69	***235,329.35***
71.06(c)	Sealed transverse contraction joints as per the drawing (except Dowels)	m	2,779.40	26.77	***74,404.54***
71.06(d)	Dowel bars (mild steel plain bars, epoxy coated) (25 mm diameter and 400 mm long at 300 mm spacing):	no	9,565.40	80.63	***771,258.20***
	Tie Bars (Ø 12 mm high strength deformed bars ,1000 mm long @ 600mm spacing, with 15cm long protective coating as per the drawing)	no	16,689.10	46.44	***775,041.80***
71.06(f)	End caps for dowels at expansion joints with compressible fill	no	48	40	***1,920.00***
71.08	Steel Reinforcement in Concrete Pavement				***0.00***
71.08(b)	High tensile steel bars (Ø14 and Ø 12 mm deformed bars for the concrete reinforcement and 39 Anchors(keys) as per the drawing)	Ton	429.24	52,310.00	***22,453,544.40***
	Separation Membrane				
	Impermeable plastic sheeting 125 microns thick	m2	69,931.80		
	OR MC-30 prime coat material to be used in the absence of impermeable plastic sheeting,application rate of 1.25lit/m2	lit	87,414.84	40.09	***3,504,460.94***
7000 : RIGID PAVEMENT TOTAL					**133,701,527.22**
Grand total of the bills without contingency					**138,347,290.85**
Add 10% for contingency					**13,834,729.09**
Add 15% VAT					**22,827,302.99**
Total contract amount (Including Vat)					**175,009,322.93**

TABLE 4.1-2 Estimated Cost and Quantity of Materials for the long Flexible Pavement at km 8+00 – 18+000

Item	Description	Unit	Quantity	Unit Rate	Amount
	5000 SUBBASE, ROAD BASE AND GRAVEL WEARING COURSE				
	5100: SUB-BASES				
51.01	Sub-base layer constructed from gravel or Crushed stone:	m^3	7,377.00	184.10	1,358,105.70
	a) Gravel sub-base (unstabilized gravel) compacted to:				-
	(i) 95% of modified AASHTO density (120mm compacted layer thickness)				-
	5200: ROAD BASES				-
52.01	Base layer construction a) Gravel base taken from cut or borrow, Gravel base (unstabilized gravel) compacted to:	m^3	29,239.00	401.08	11,727,178.12
	(i) 95% of modified AASHTO density (150 mm compacted layer thickness)				-
	6000 BITUMINOUS SURFACINGS AND ROAD BASES				
	6100 BITUMINOUS PRIME COAT				
61.01	Prime coat				
	(a) MC-30 cutback bitumen	Lt	40,955.90	40.09	1,641,922.03
6200	**Tack Coat**		-		-
61.03	RC -70 Cut back bitumenapplied at 1lit per sq.m	Lt	205,852.51	38.19	7,861,507.36
	6300C: DOUBLE SURFACE TREATMENTS				
63C.01	Double surface treatment using				
	(c) Double surface treatment using 20 mm and 10 mm chippings (with MC 3000 cutback)	m^2	80,882.68	109.73	8,875,256.48
63C.02	Variations in the rate of application of Bituminous Binder,with MC 3000 cutback	Lt			
	(h) MC 3000 cutback bitumen	Lt	5,877.00	47.38	278,452.26
63C.03	Variations in the rate of application of Chippings		-		-
	(a) 20 mm chippings	m^3	1,273.38	536.79	683,537.65
	Variations in the rate of application of Chippings		-		-
	(b) 10 mm chippings	m^3	587.71	-	-
6400	BITUMINOUS Road Bases and Surfacing				-
64.02	Asphalt Surfacing				-
	(iii)(a)50mm A sphaltic Surfacing with pentration grade 80/100 Bitemen	m2	50,746.31	213.01	10,809,471.49
	(b) Dense Bitumen Macadam (145mm)	m^3	9,098.77	3,254.17	29,608,944.37
Total (birr)					**72,842,526.05**

TABLE 4.1-3 Estimated Cost and Quantity of Materials Reinforced concrete Vs. Flexible Pavement km 8+000 –18+000. Relative Estimated Costs for the introduction of rigid pavement

No.	Rigid Pavement Detail	*Estimated Rigid Pavement Cost*	*Estimated flexible pavement cost*	*Estimated total Additional cost with respect to The rigid pavement type*
1	10 Km full width Reinforced concrete(340 mm thick, C-35, reinforcement =600 mm2/m, joint length=25 mts	175,009,322.92	72,842,526.05	102,166,796.87

Figure 4.1-1 Cost Comparison for the 10Km long Flexible and Rigid Pavement throughout the Design life

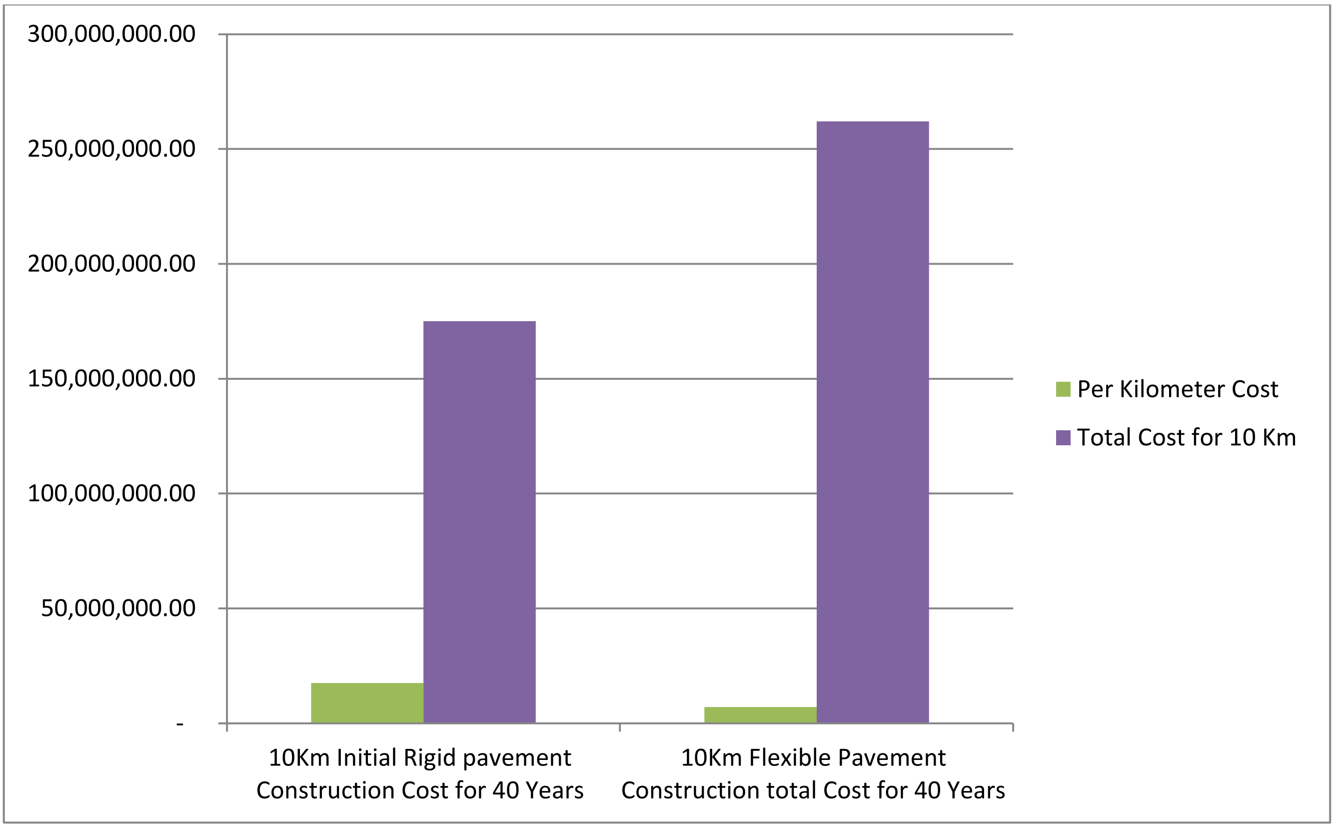
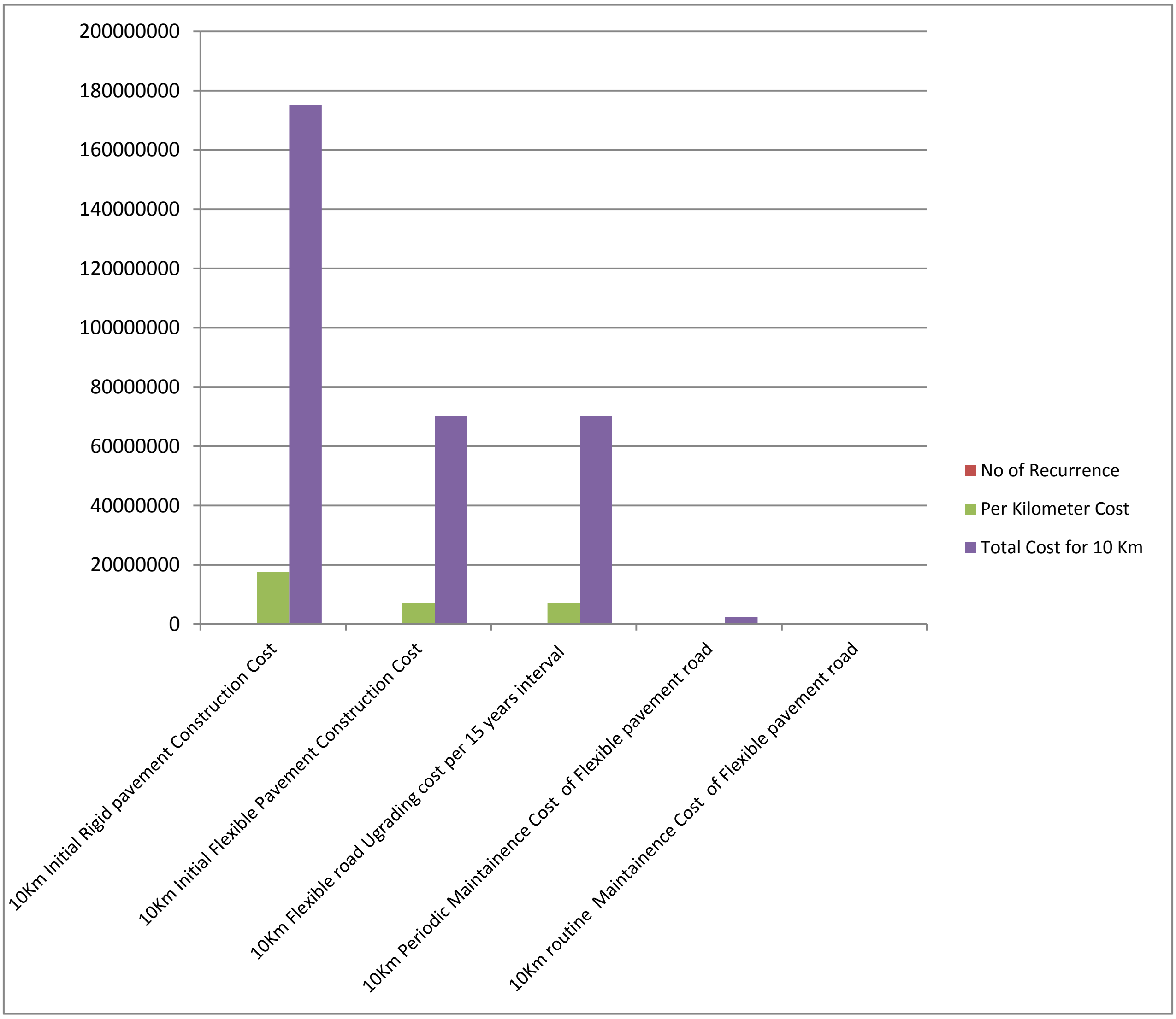


Figure 4.1-2 Cost Comparison for the 10Km long Flexible and Rigid Pavement throughout the Design life including the upgrading, periodic and routine maintenance cost



CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

1. A total of 10km flexible pavements and rigid pavements costs are designed and their costs computed in the paper and rigid pavement cost is higher than flexible cost by 41 %.

2. Moreover, considering the cost of 40 years maintenance cost (Upgrading, Periodic and Routine) estimated per kilometer cost is 7,037,685.14 ETB, 234,589.50 ETB and 7,819.65 ETB ,Hence it would have 50% reduction and it is viable to use rigid pavement in the construction sector Ethiopia is undertaking.

3. The development of cement factories in number and size against the importation of bitumen for asphalt works justify the adoption of rigid pavement on high traffic sections.

5.2 Recommendation

In the long term the construction of rigid pavement for high traffic loading areas is advantageous. Hence, the Ethiopian Roads Authority and other companies are highly advised to adopt rigid pavement.

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10. (Interim Payment Certificates of Chancho-Derba- Becho Road Project., 2015)

Appendix

Photo shows Dowels bars and Joint Spacing

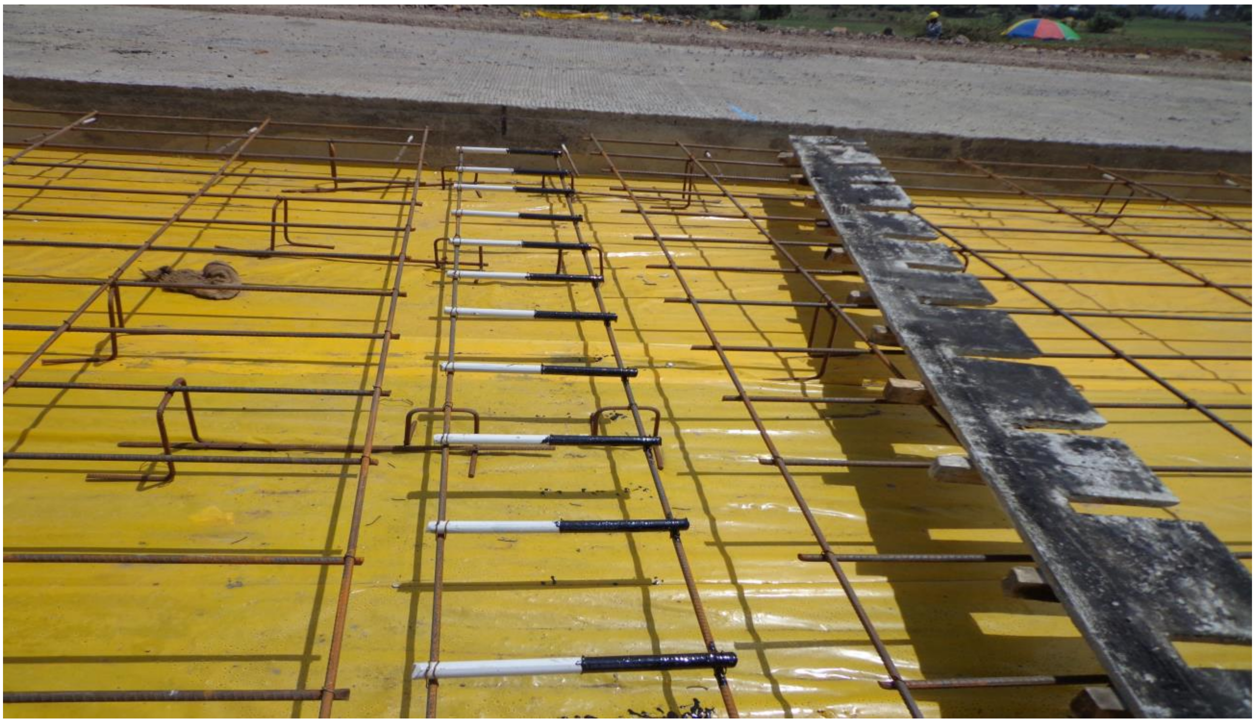

Photo shows Placing of Concrete by Concrete Paver and Vibrator

Photo shows Placing of Concrete By Concrete Paver and Vibrator

Photo shows Finishing work of rigid pavement construction